Determining tropical width and TTL boundaries using trace gas, cloud, and aerosol observations

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SAGE Science Team Meeting, October 14, 2022

Report on My Recent Research In Colorado: Meditations from my local craft brewery.

Science Questions:

How large is the head on a beer?

What processes impact the volume of this foam?

What residue does the foam leave behind?

How will the head on this beer change over time?

→ **Will this help us to get new insight into the tropical tropopause layer?**

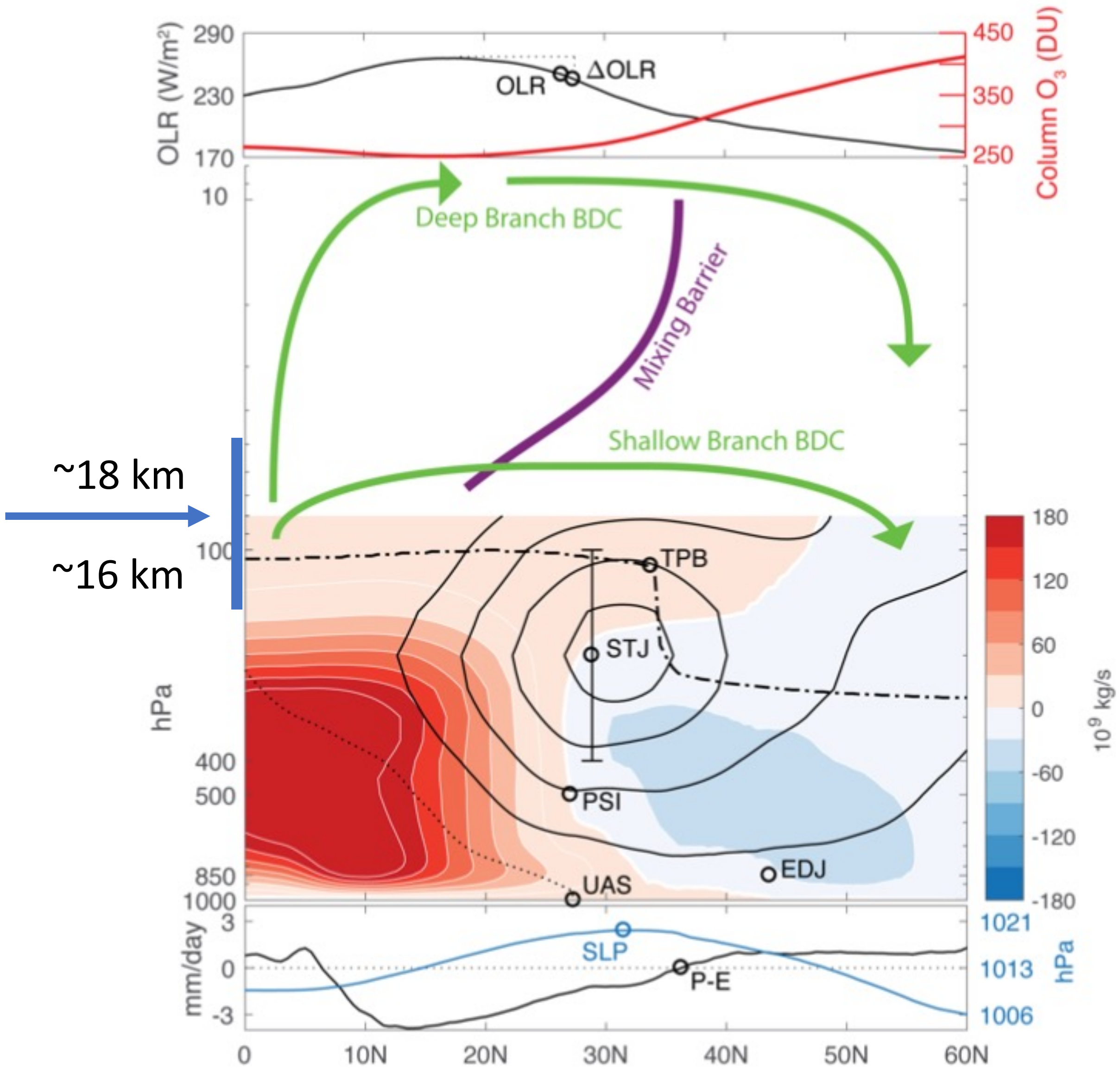
Objective: Create a new metric for defining the boundaries of the Tropical Tropopause Layer (TTL) using high vertical-resolution SAGE-III/ISS and CALIOP Observations

Roadmap to Our Talk:

- Introduction to Tropical Width and "ISSI TWIST"
- Testing out new observational metrics
- **What about SAGE-III/ISS clouds and aerosols?**
- Cloud/Aerosol Discrimination, what can we learn from SAGE-III/ISS?
- "I've looked at clouds from both sides now…": **CALIOP and SAGE-III**
- How do ozone and water vapor distributions compare? **CALIOP and MLS**
- Getting off the "Zonal Mean Highway"

GOAL: **Use the golden age of satellites observations to evaluate longer climate data records.**

Background: Tropical Width



Northern Hemisphere - Latitude

“Width of Tropics” Metrics

- Column Ozone
- Outgoing Long-Wave Radiation
- **Tropopause Break**
- **Subtropical Jet**
- 500 hPa streamline =0
- Eddy-Driven Jet
- Surface zonal wind
- Precipitation-Evaporation
- Sea-Level Pressure

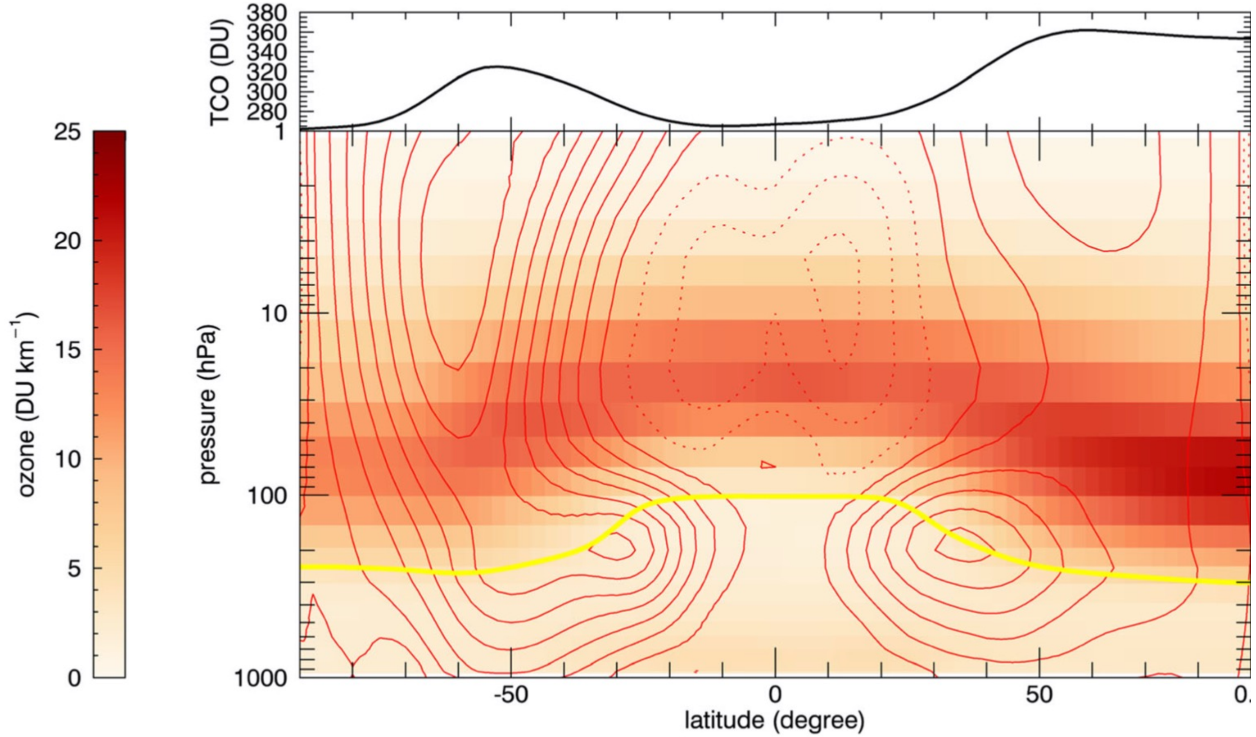
Testing out new observational metrics

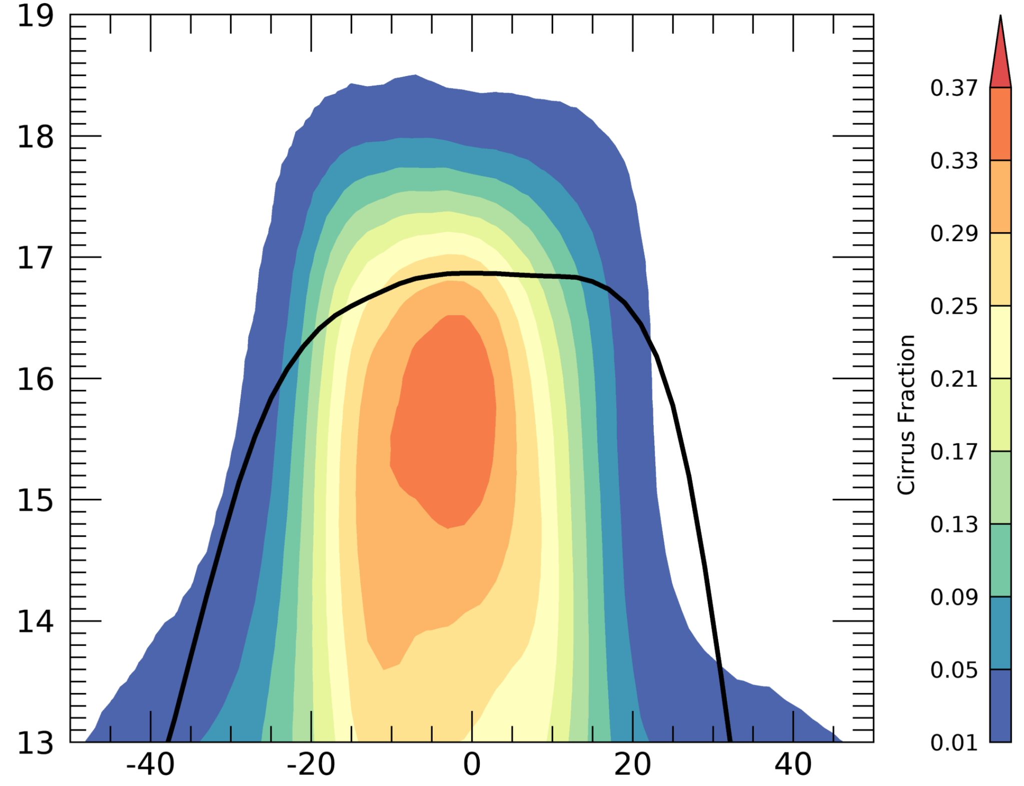
- Motivation:
  - Most estimates of historical tropical width changes are based on reanalyses (models)
  - **We're considering new metrics based on independent (non-assimilated) measurements**
- Methods:
  - Generally, variables have a meridional gradient that we are exploiting to identify a tropical "edge" latitude
  - Compute new metrics and compare correlations to other metrics (seasonal, interannual)
  - Look at trends
  - Compare to models
  - Consider zonal asymmetries
  - Consider a TTL volume

What is the ISSI TWIST project? ISSI TWIST Goals:

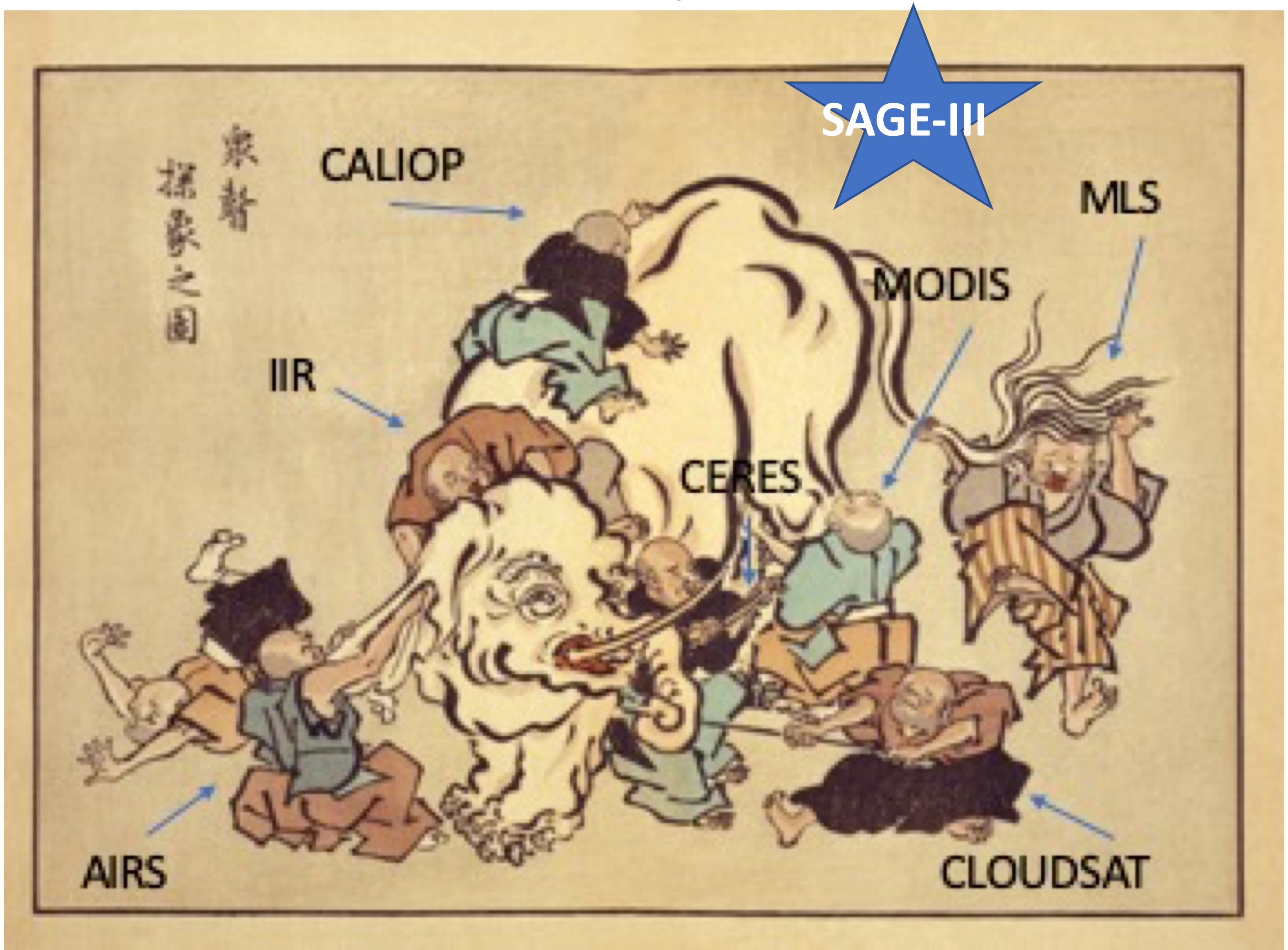
1. Identifying robust satellite-observed metrics of tropical width in the UTLS
2. Characterizing relationships between UTLS tropical width and circulation
3. Identifying how tropical width variations in the UTLS relate to variability and trends in trace gas concentrations

Instead of using the reanalysis data or total column ozone, we're using observations to investigate tracer and other gradients at specific levels.



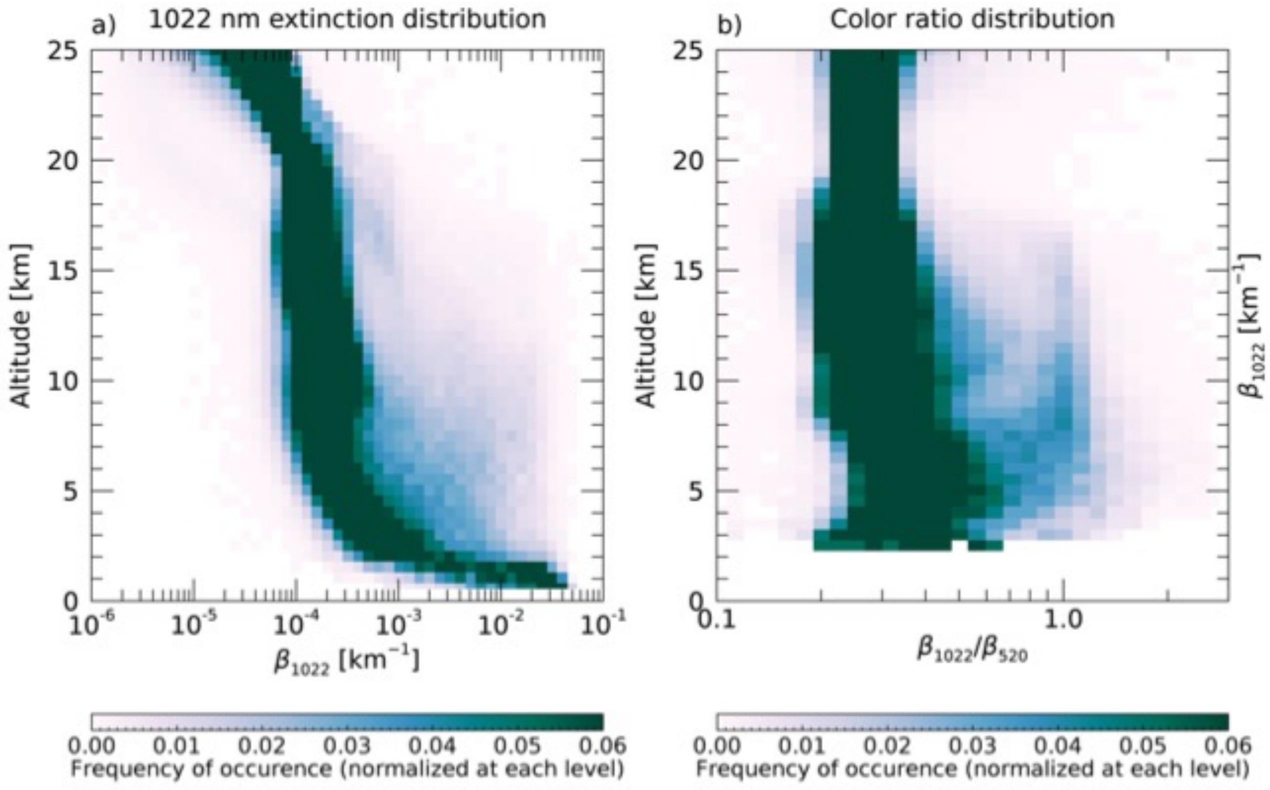


This IS a SAGE Science Team Meeting.
What About SAGE-III/ISS Observations?

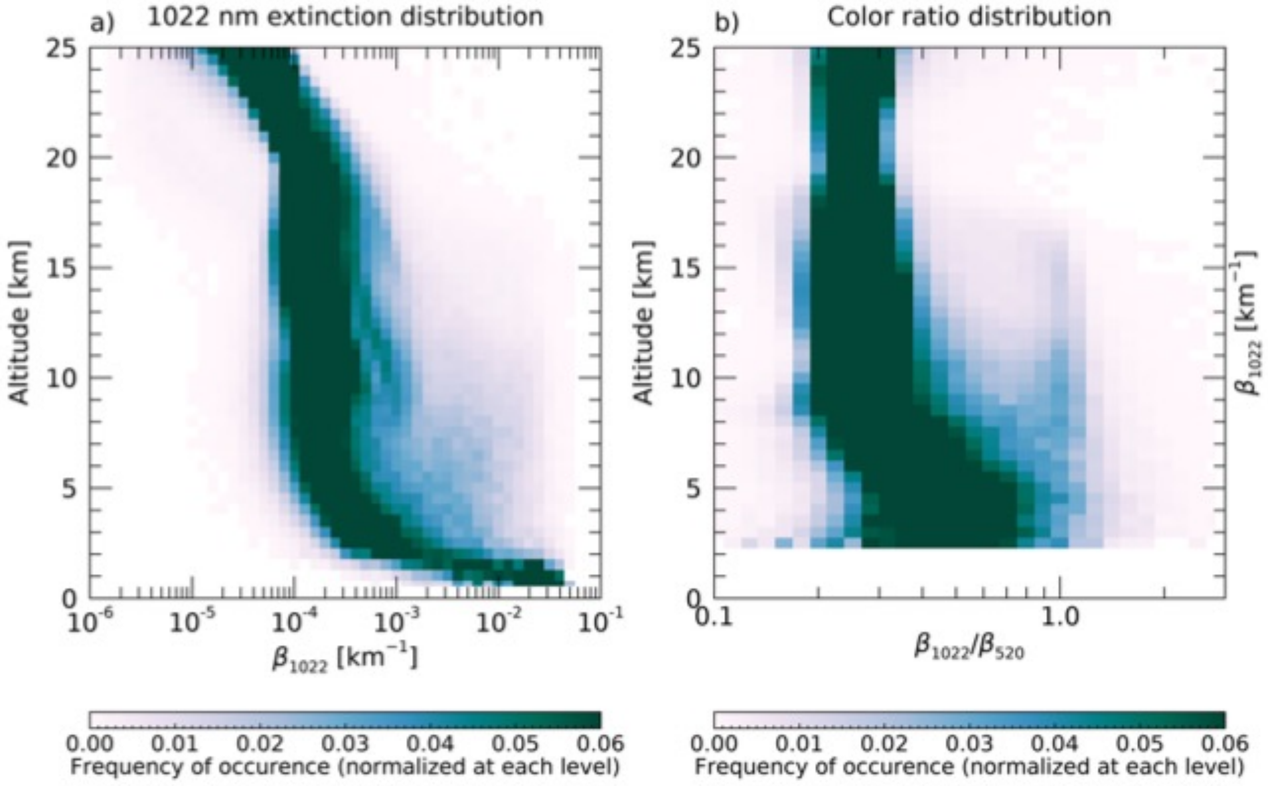


SAGE-III/ISS Version 5.1 vs Version 5.2 – 1022 nm Extinction Coefficient Ratio and 520 nm/1022 nm Color Ratio

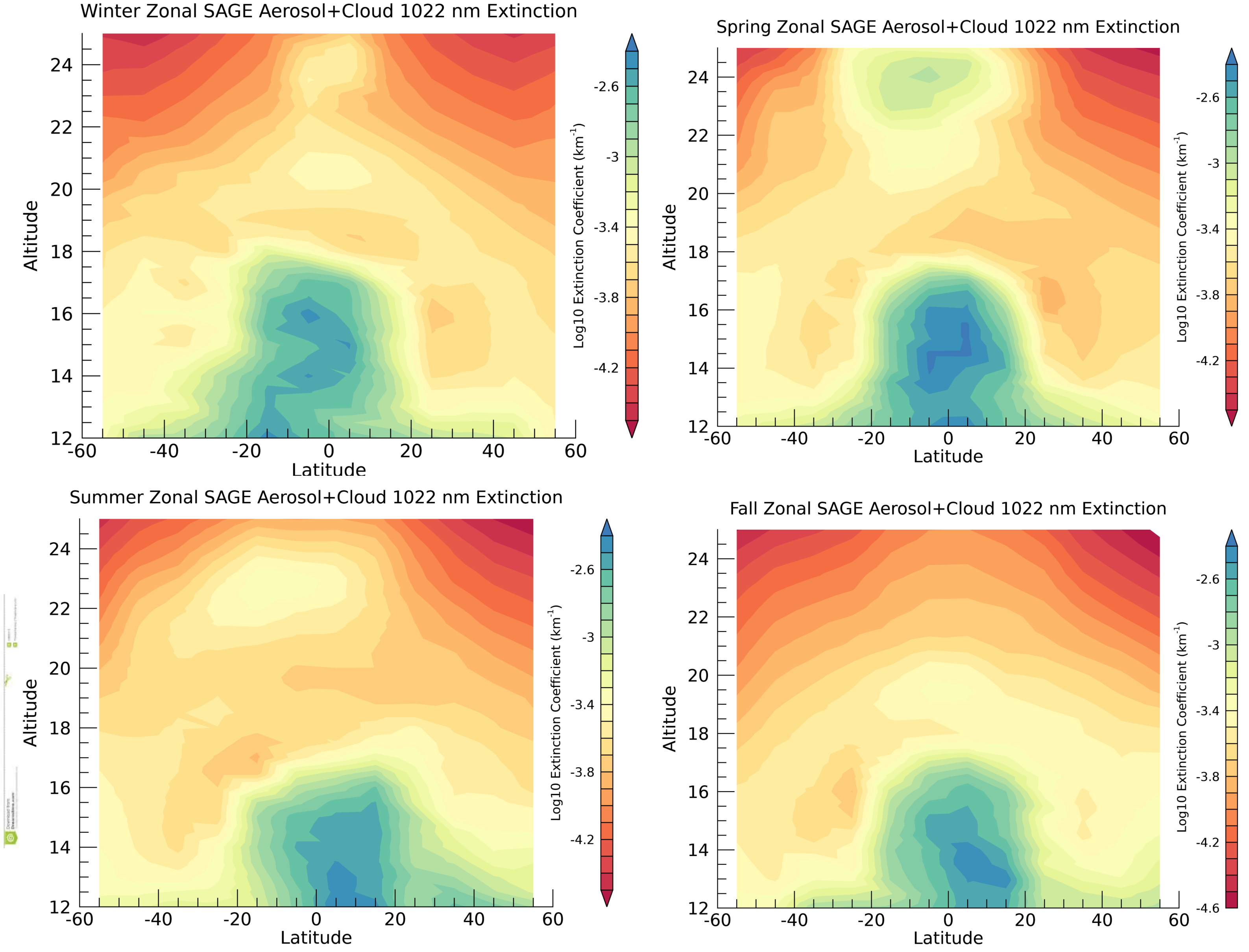
V5.1



V5.2



SAGE-III/ISS 1022 nm Seasonal Zonal Mean Extinction Coefficients All-Sky, All Particles (Ice + other Aerosols), 2017 – Jan. 2022



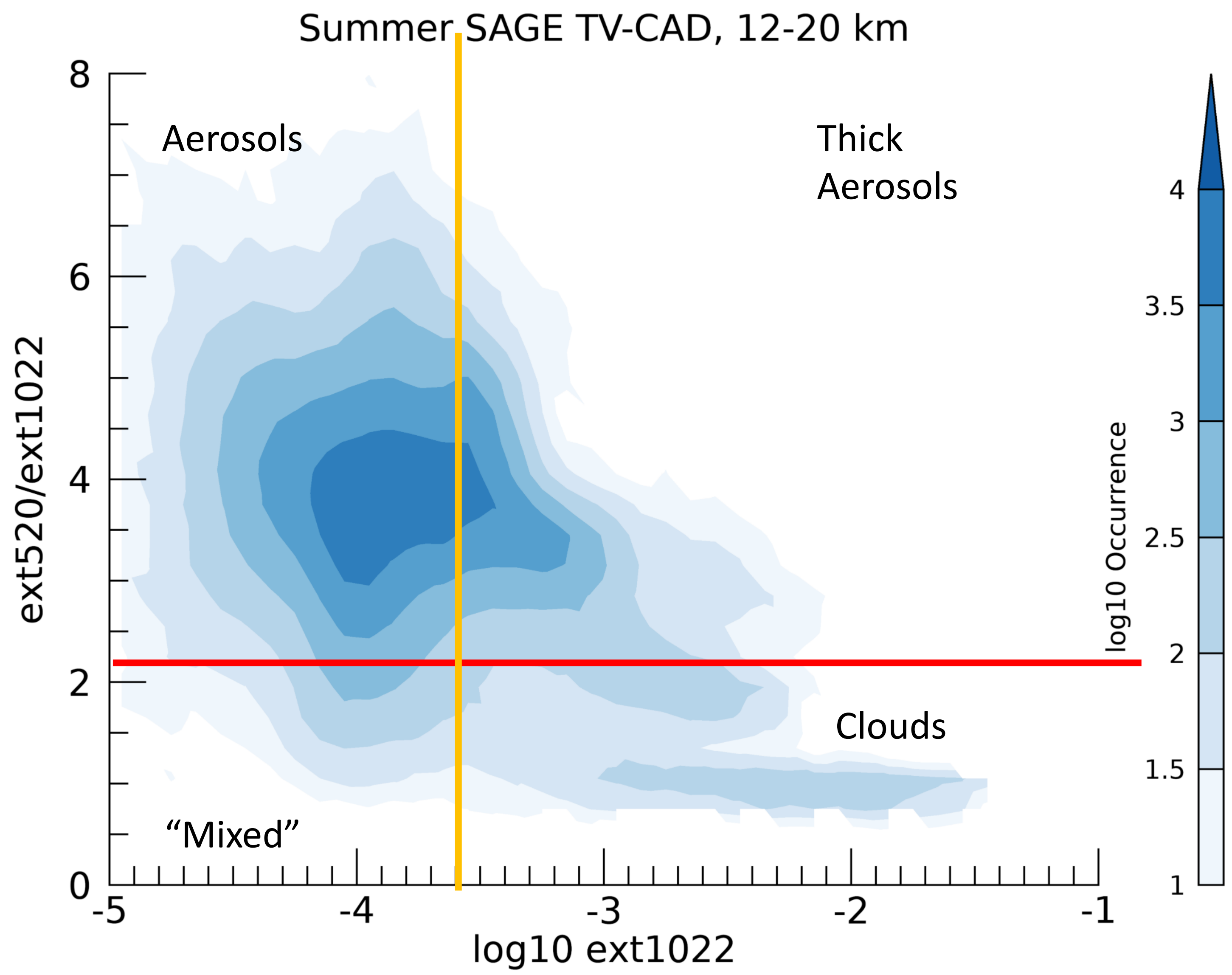
Data Analysis for SAGE Extinction Profiles:

Seasonality uses Boreal labeling, Typical DJF, etc.

June 2017 – January 2022

Extinction Uncertainty < 100%

Thomason and Vernier, 2013: SAGE Cloud/Aerosol Discrimination

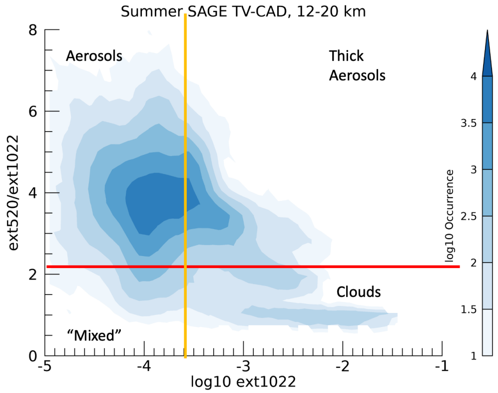


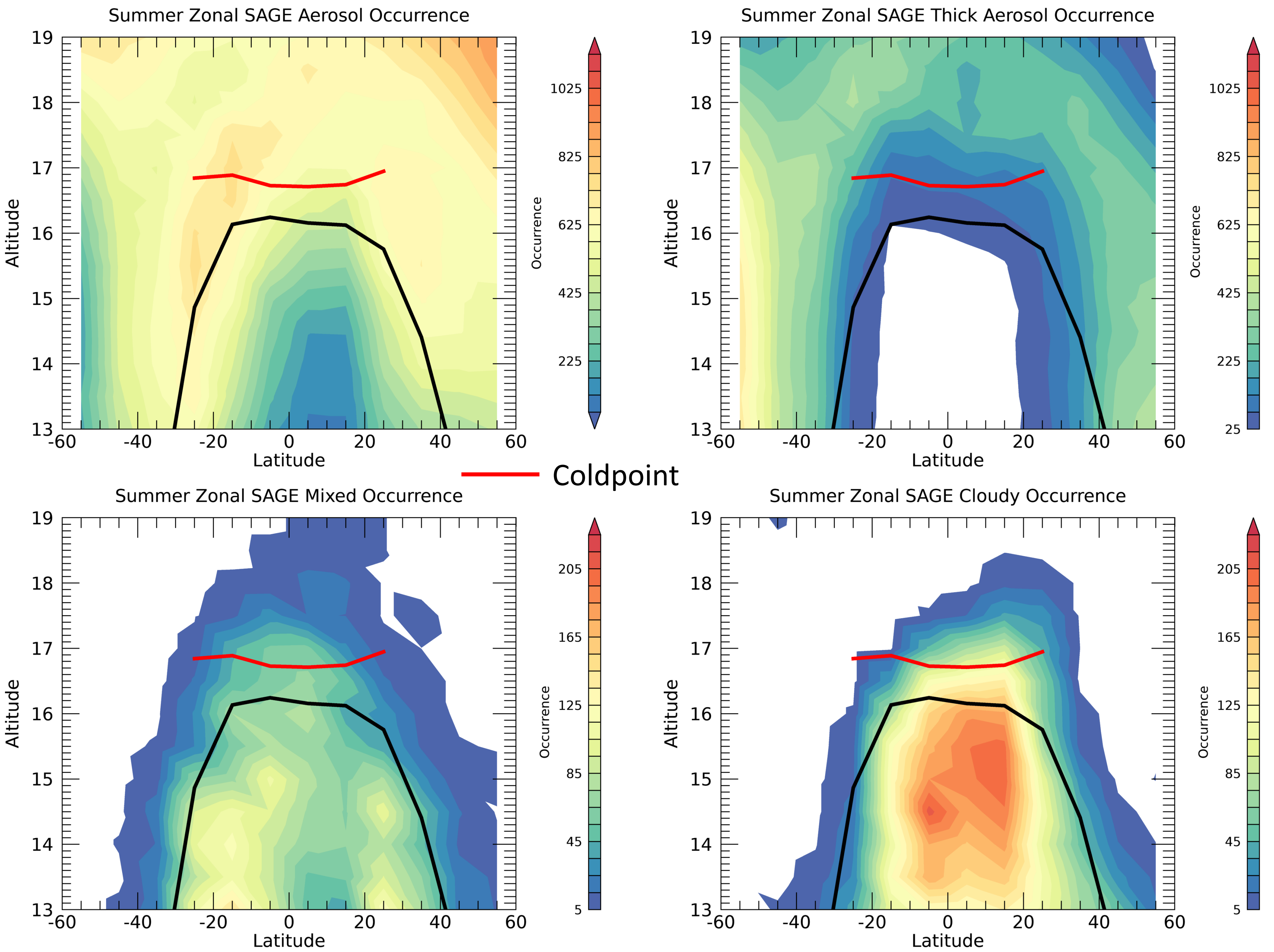
"Color Ratio" Threshold moved up by 10%

Summertime Zonal Means as segments of the TV CAD

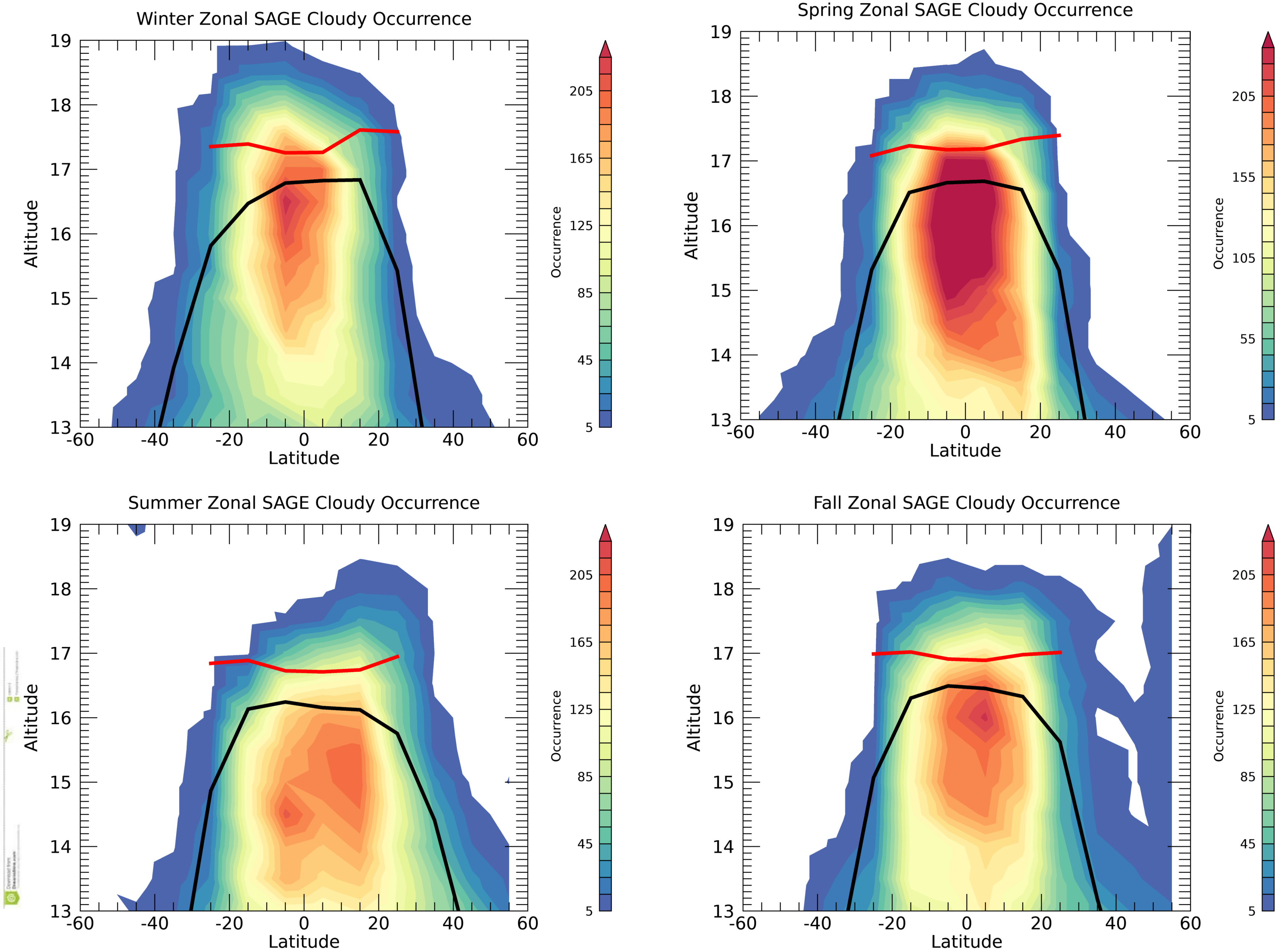
Scales on top and bottom row of plots are not the same!

Observation:
CR appears to more effectively separate the tropospheric from the stratospheric features

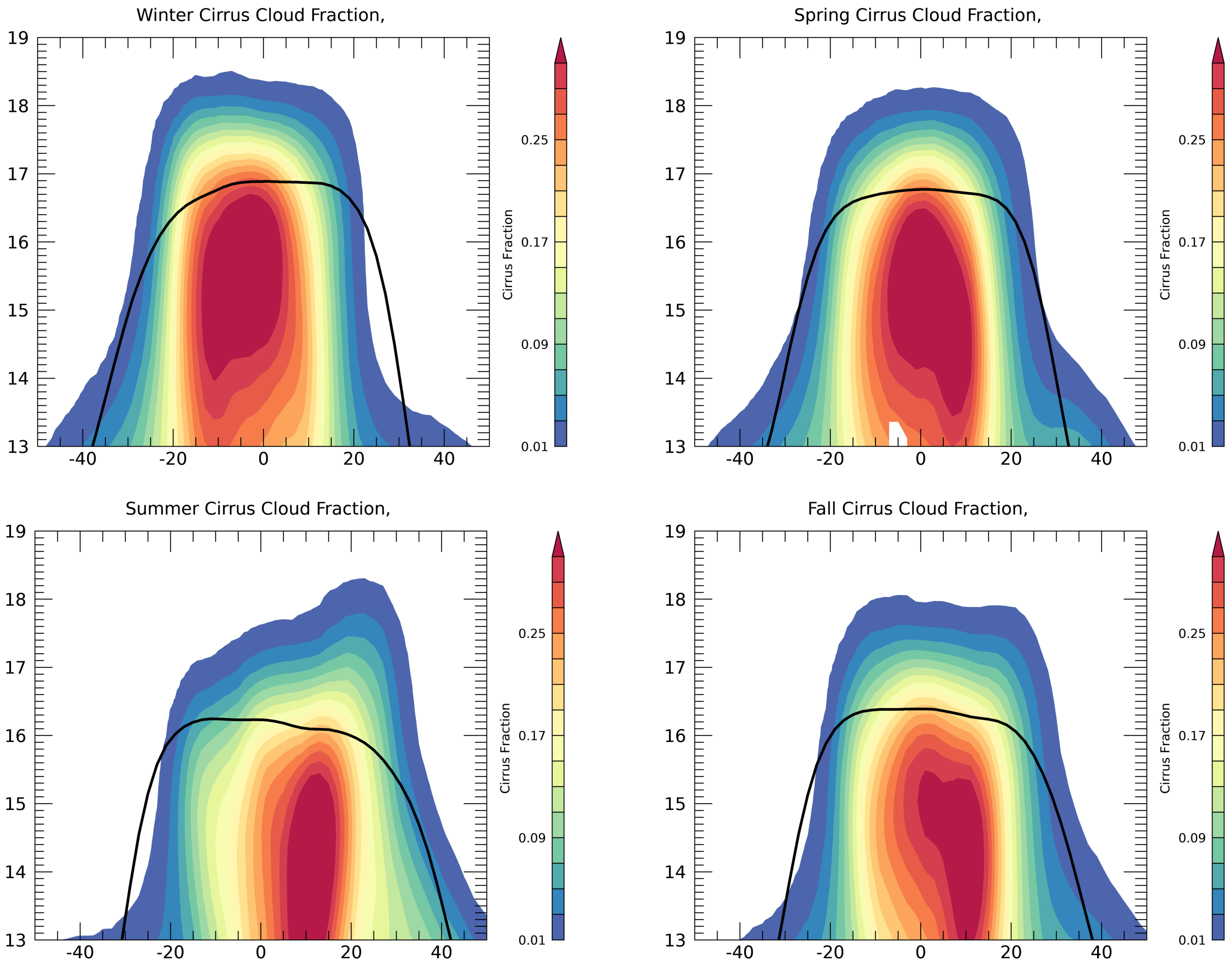




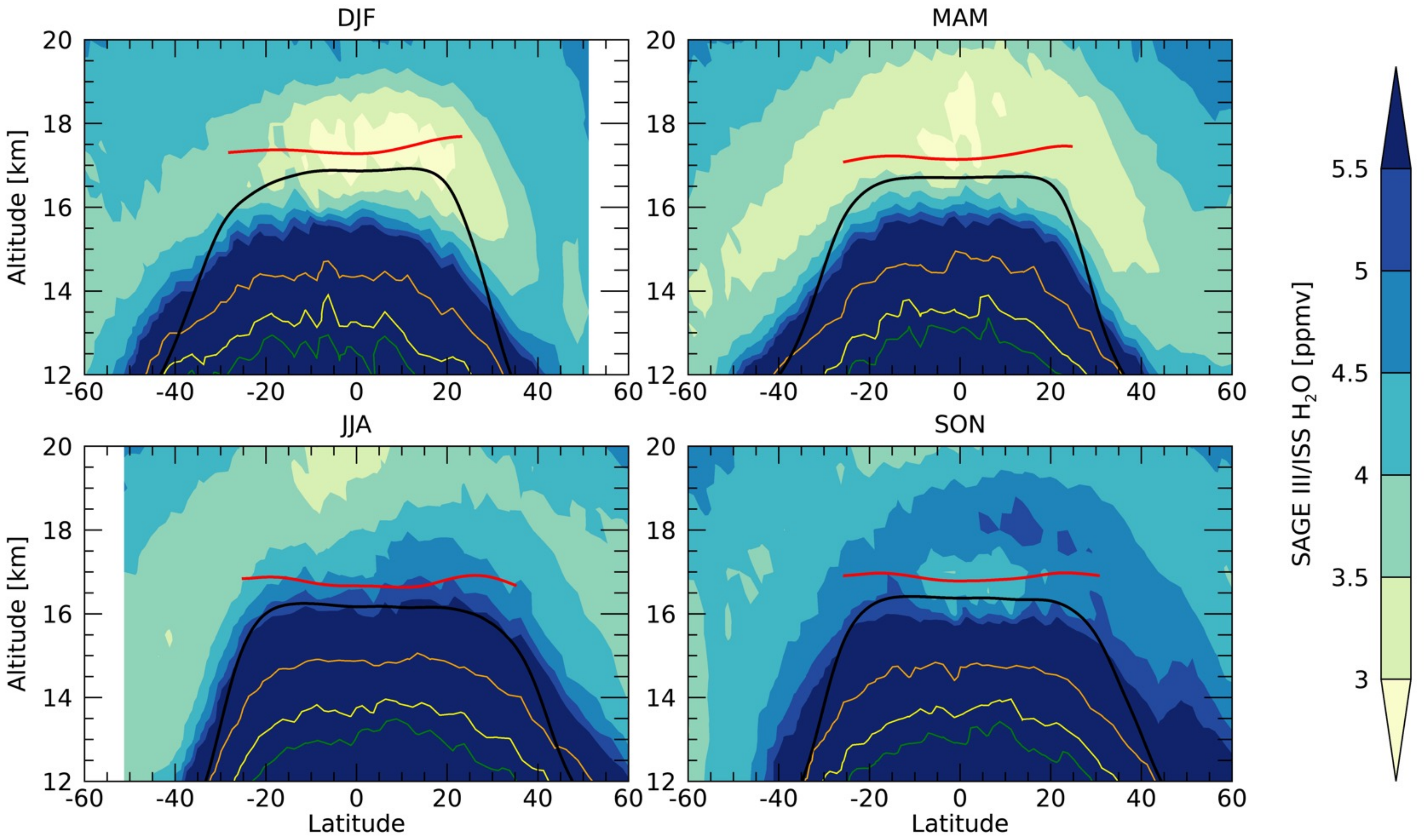
Seasonal Cloudy Bin Occurrence, SAGE-III (Latitude-Normalized)



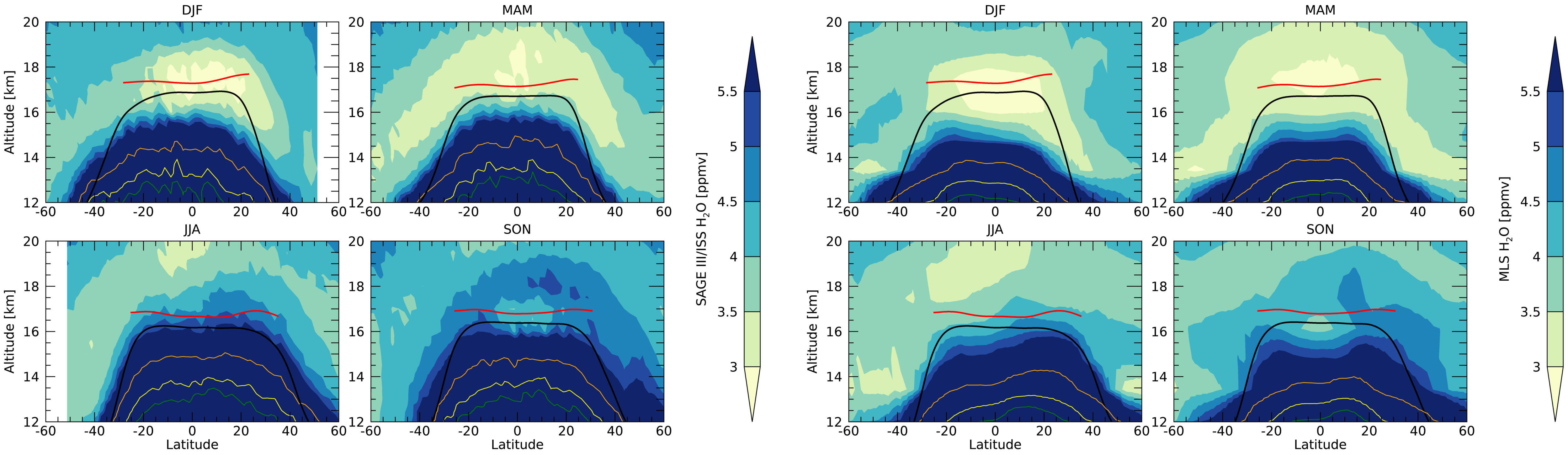
CALIOP Transparent Cirrus Cloud Fraction, CALIOP



SAGE Water Vapor – Native SAGE Data Resolution

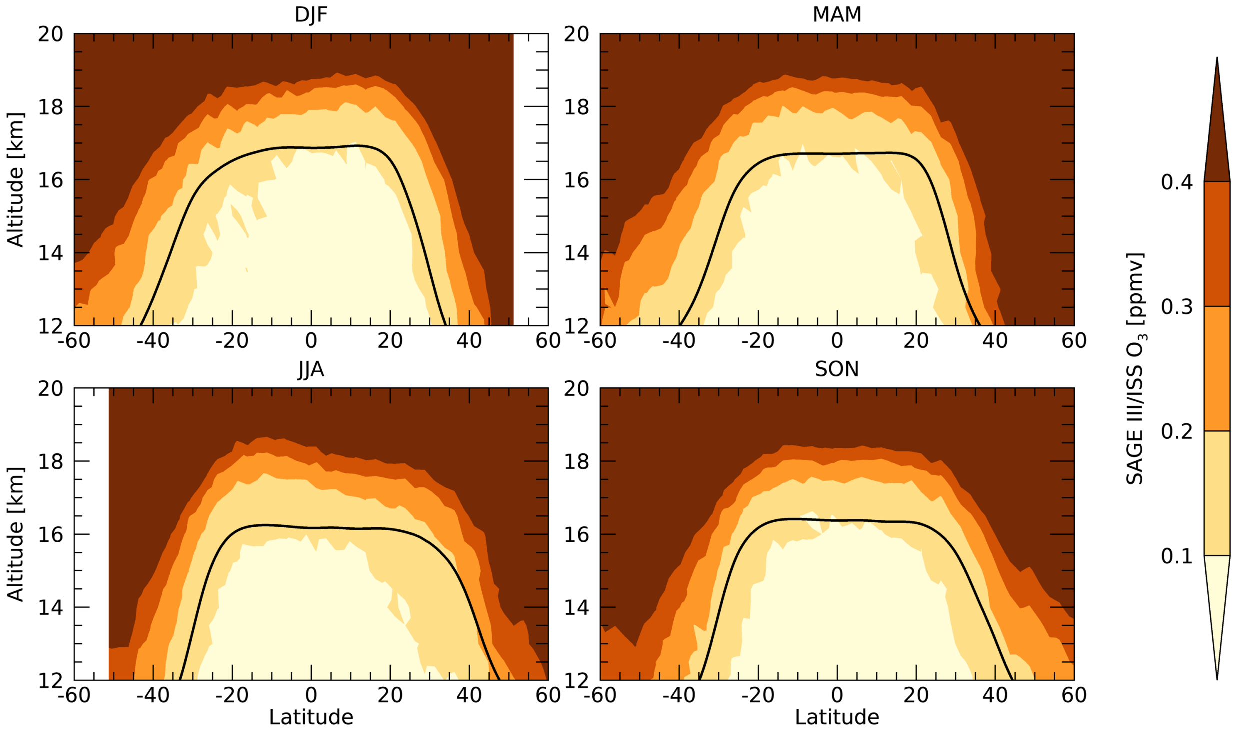


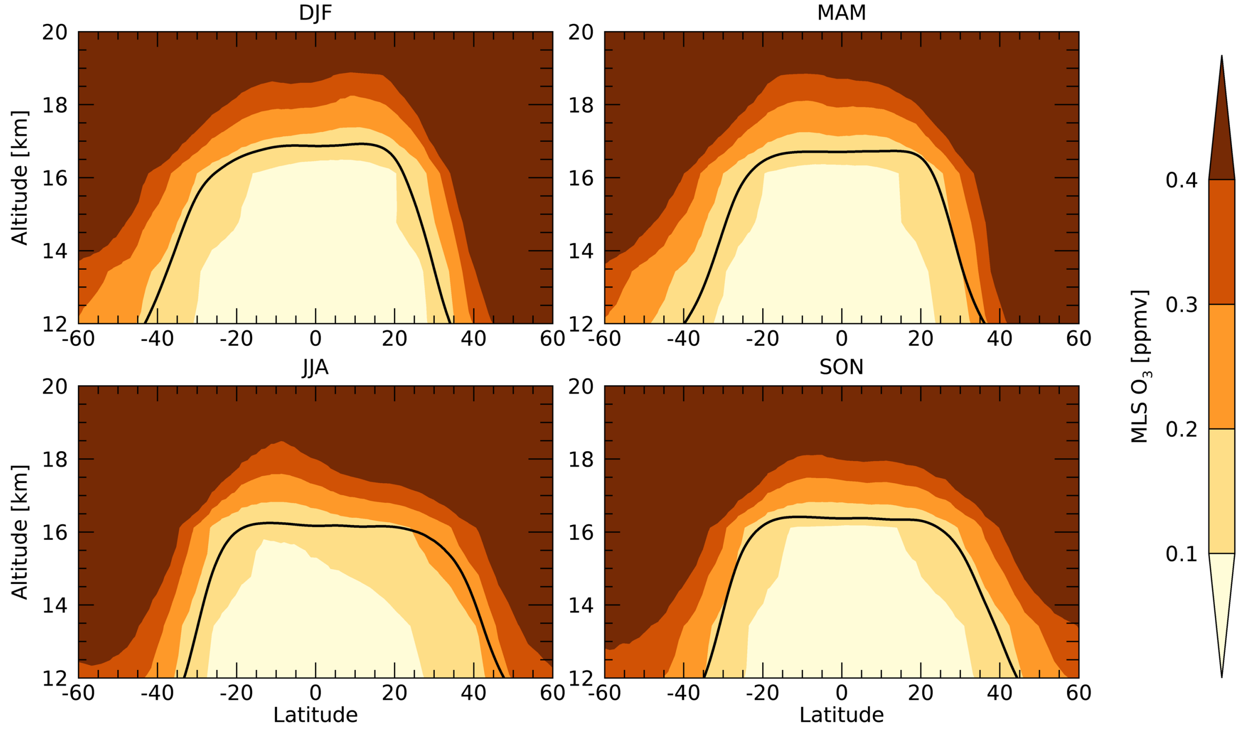
SAGE (LHS) vs MLS (RHS) Seasonal Median Water Vapor



MLS/SWOOSH pressure levels have been converted to geopotential height using a scale height of 7 km for both data sets.

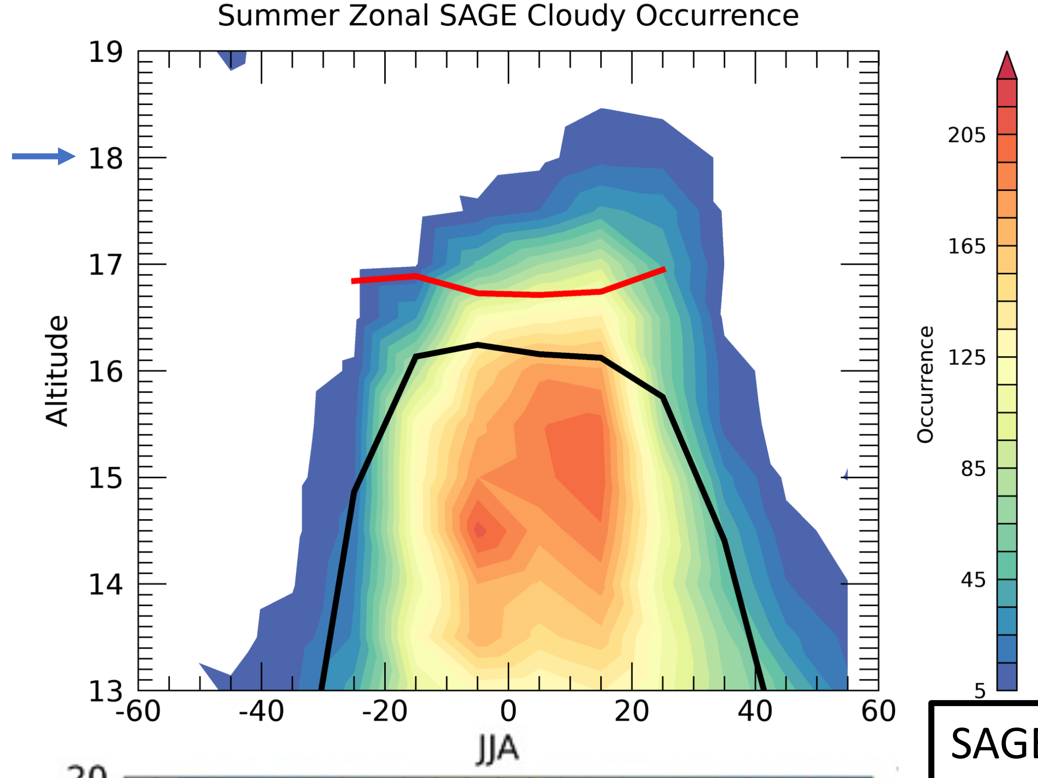
SAGE (LHS) and MLS (RHS) Seasonal Median Ozone



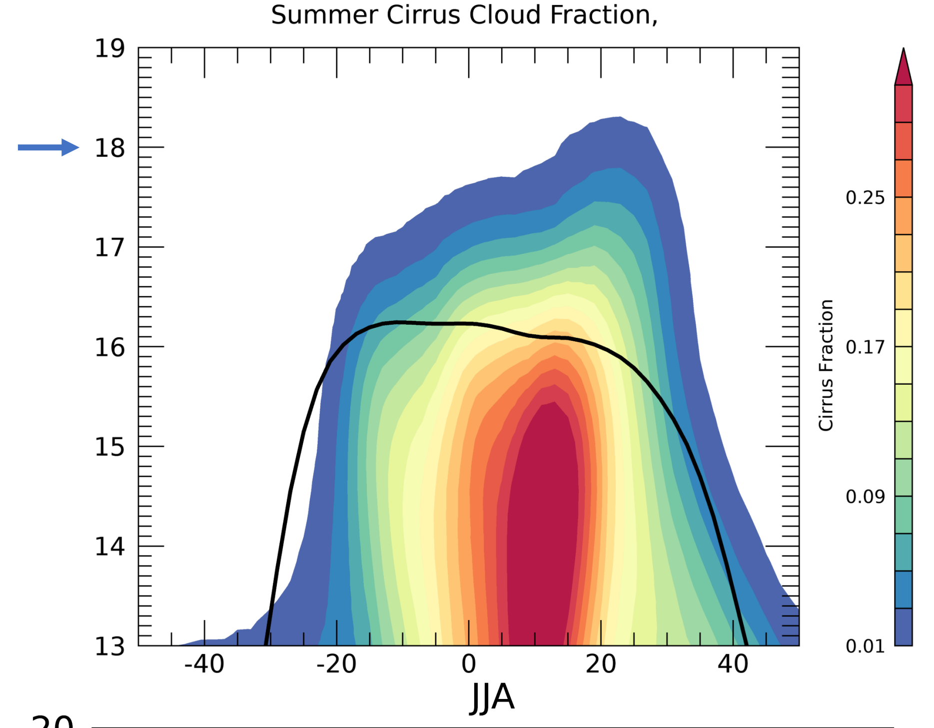


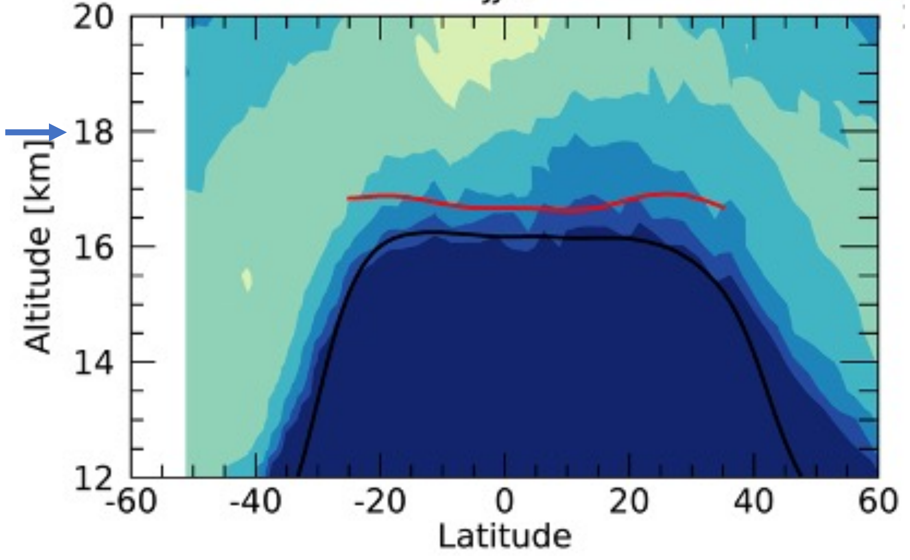
MLS/SWOOSH pressure levels have been converted to geopotential height using a scale height of 7 km for both data sets.

Summer (JJA) Summary, SAGE and CALIOP

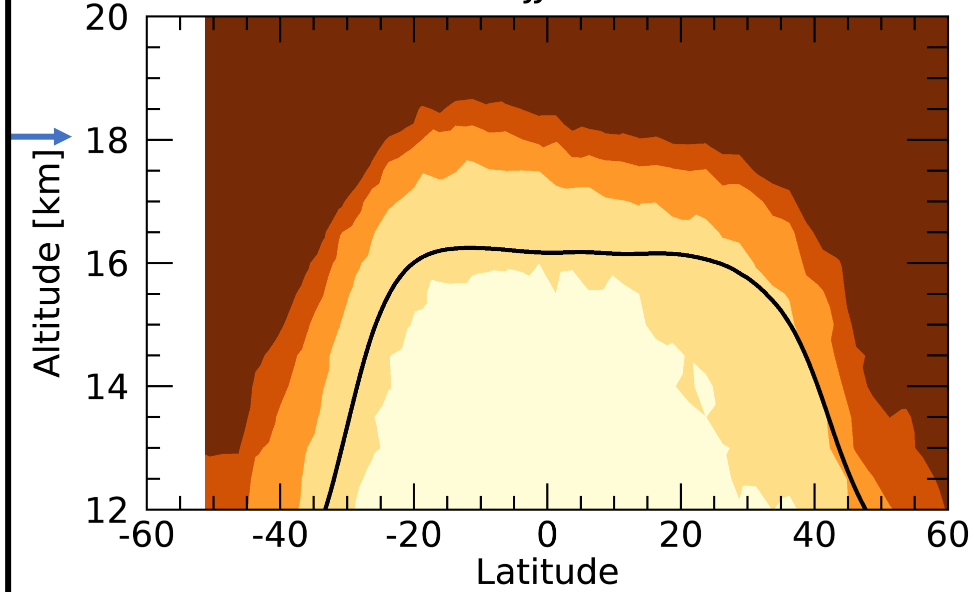


SAGE-III and CALIOP cloudy distribution match up, with cloud tops during the Asian Monsoon to 18.5 km, and NH TB at ~35N

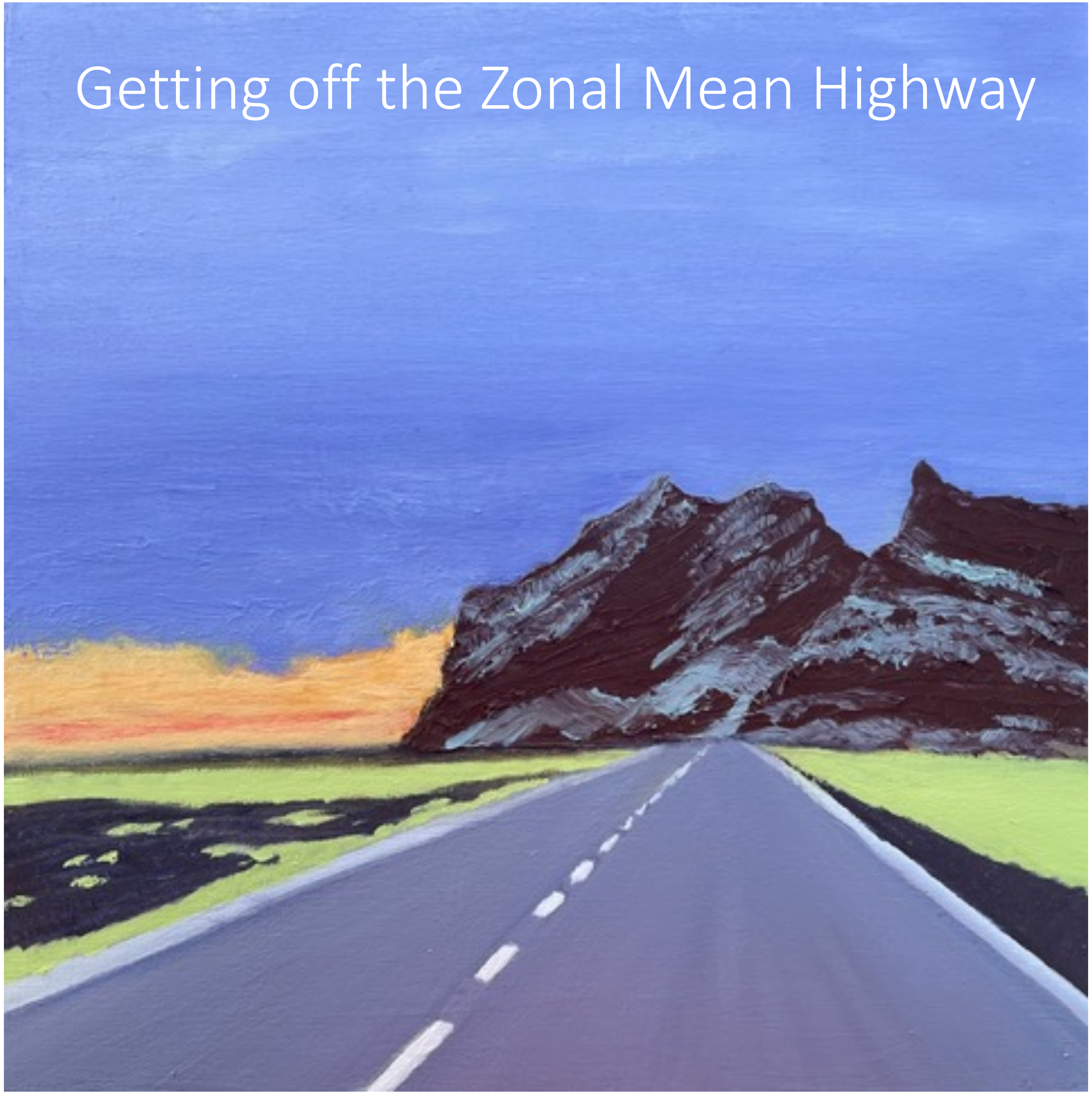




SAGE-III water vapor distributes in a similar way to cloudy observations in the Asian Monsoon region, but ozone does not. The ozone pattern favors the stratospheric seasonal circulation, while water vapor follows convection.



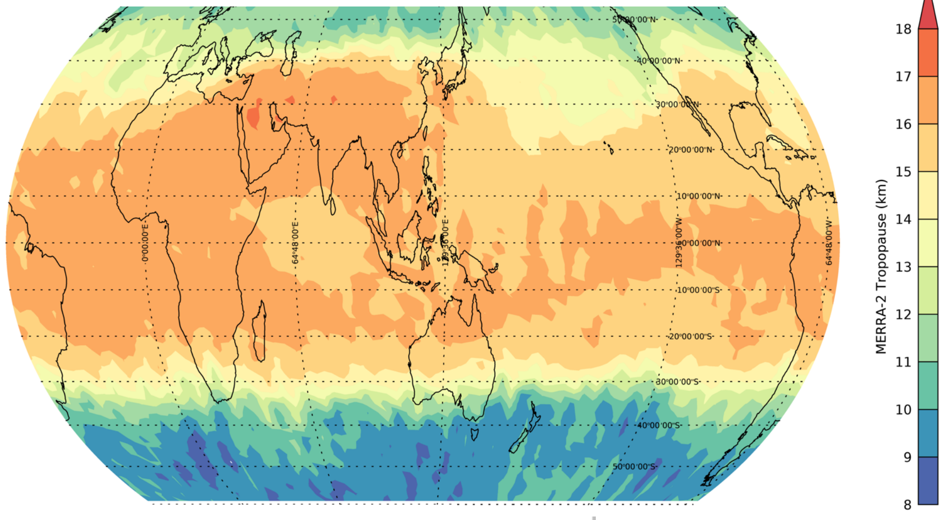
Getting off the Zonal Mean Highway



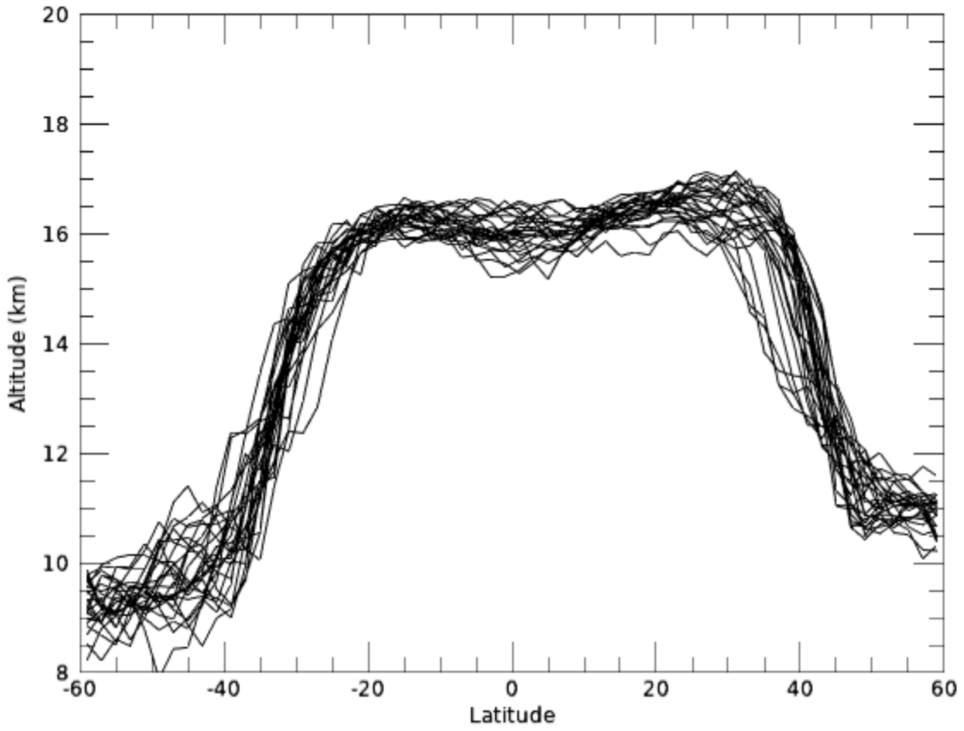
Asymmetries in the Tropopause

Merra-2 Tropopause, 2013

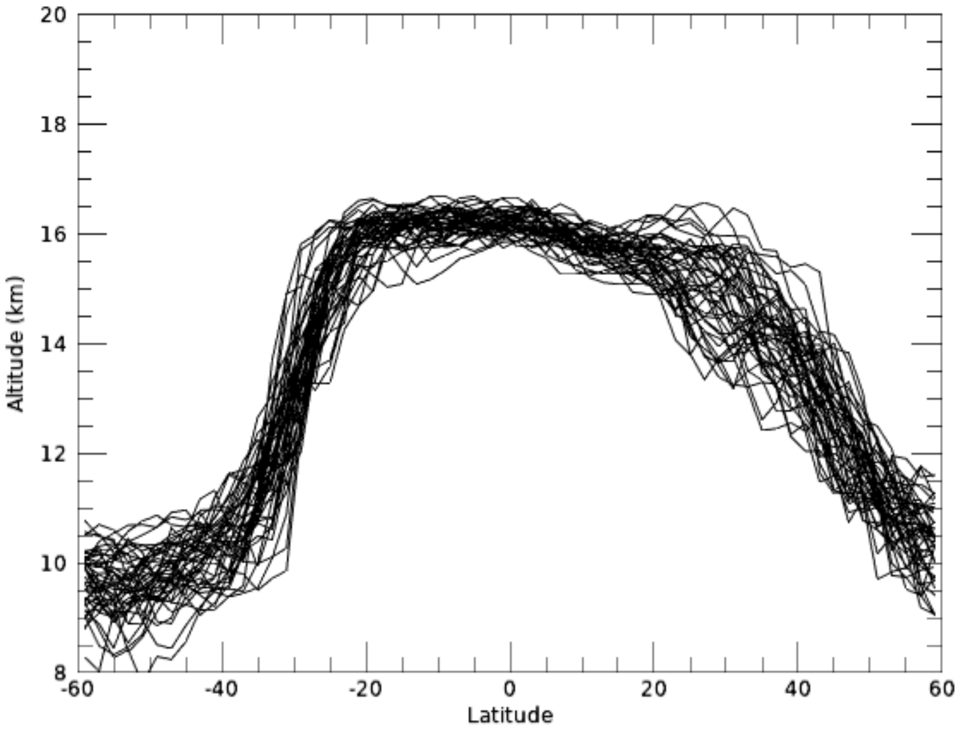
Tropopause Height – Typical August



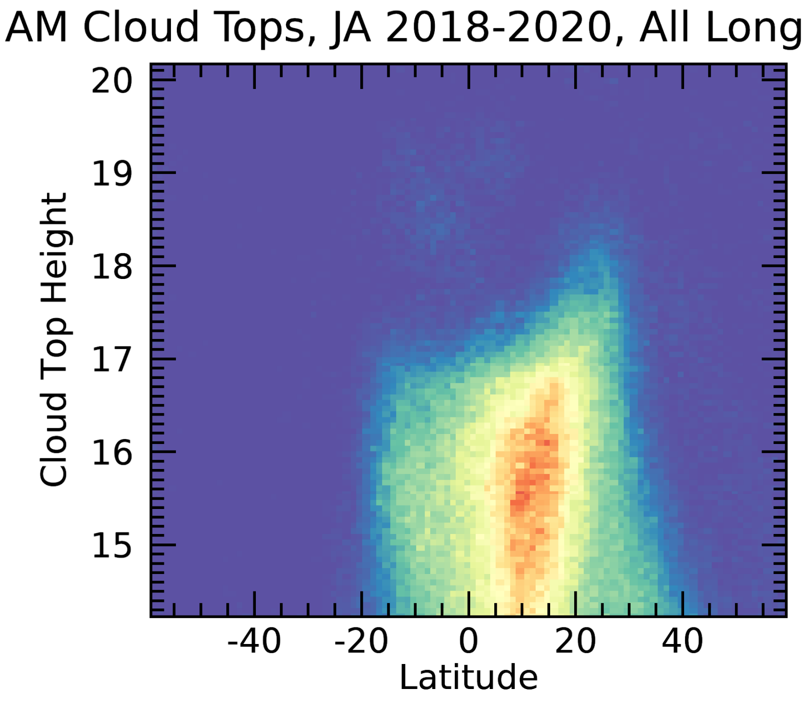
August, 5E – 105E

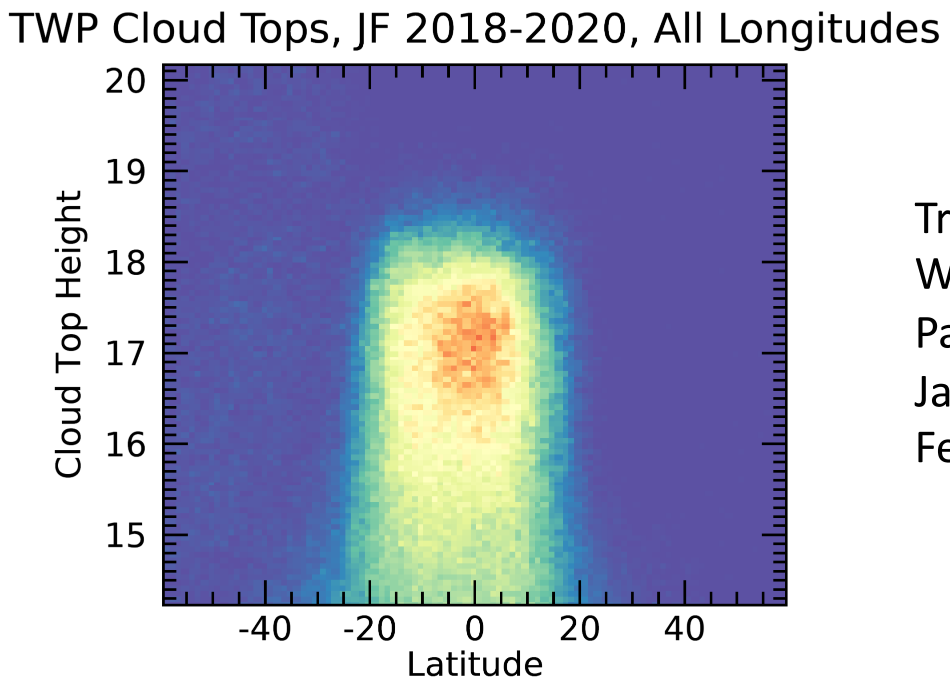


August, 0 - 5E, 105 - 180E, 0 – 180W

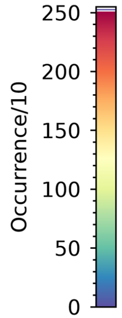


Asian Monsoon, July and August

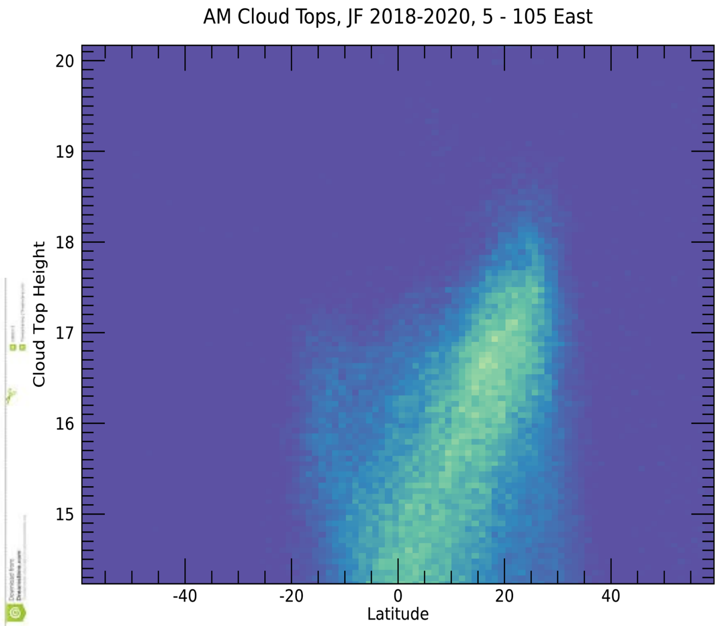


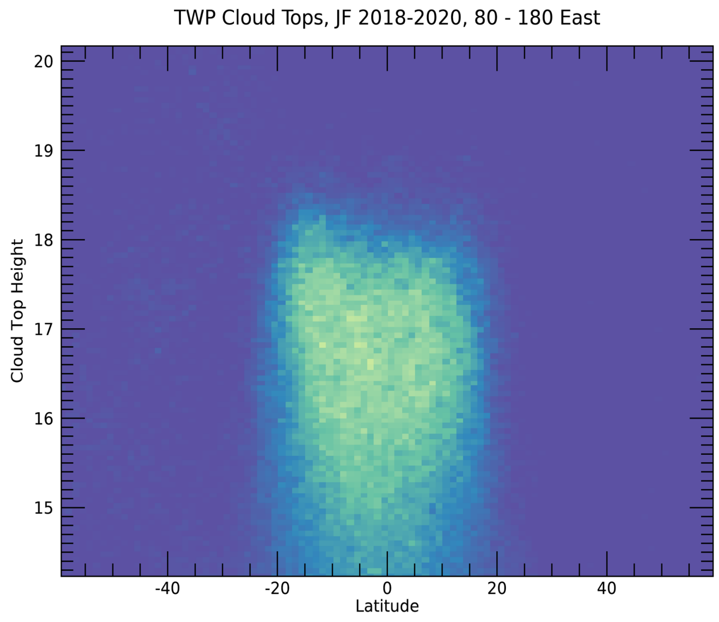


Tropical Western Pacific, January and February



Asian Monsoon, 5 – 105 East

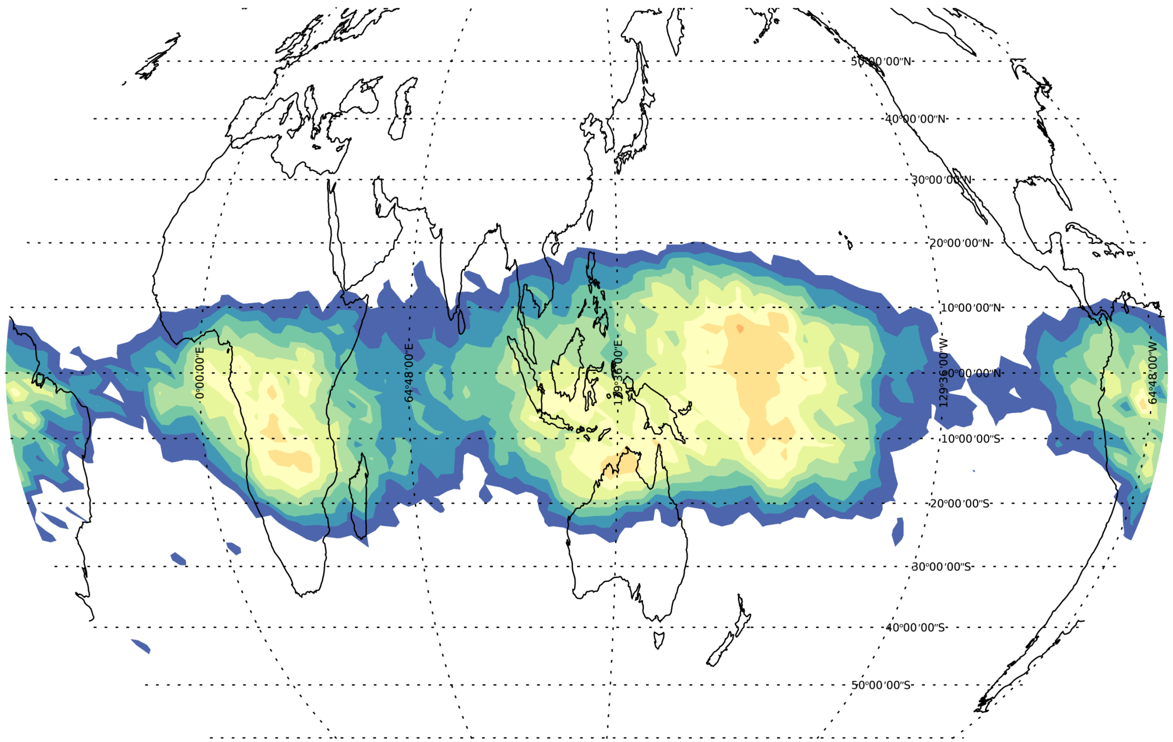




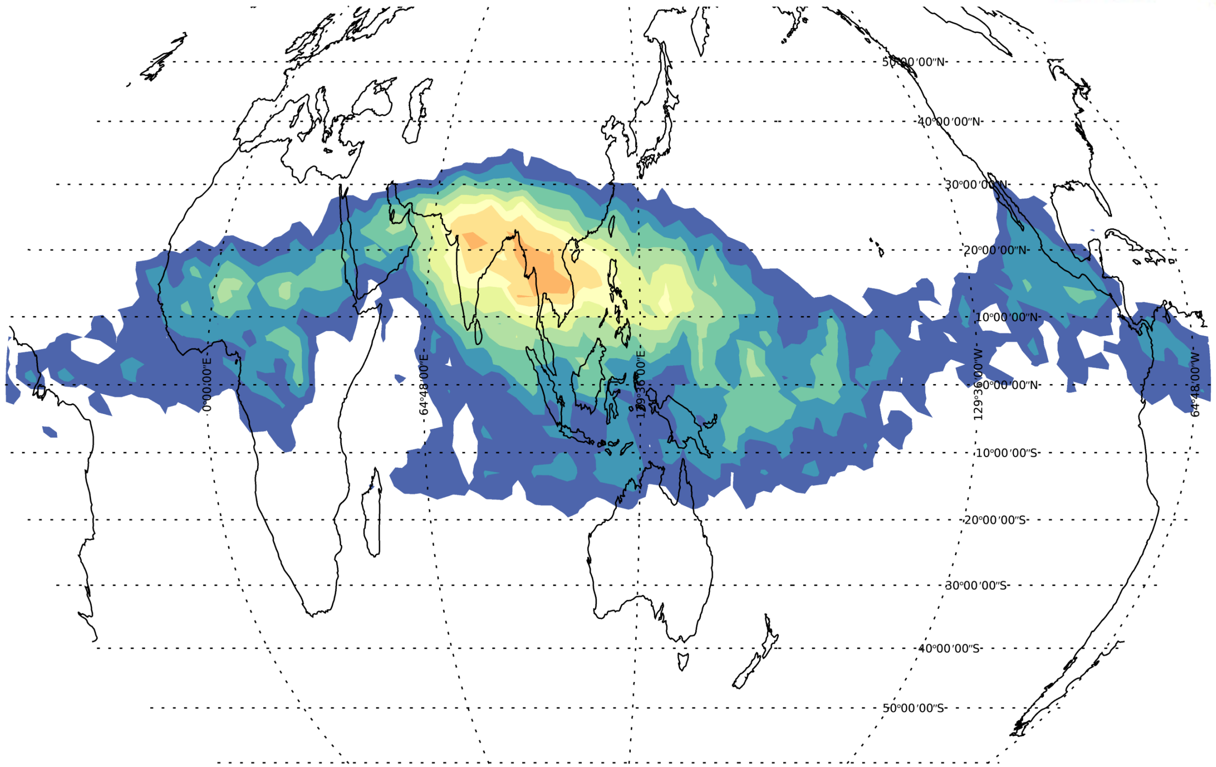
Tropical Western Pacific, 80 – 180 East

Seasonal Changes: JF (LHS) vs JA (RHS)

January and February



July and August

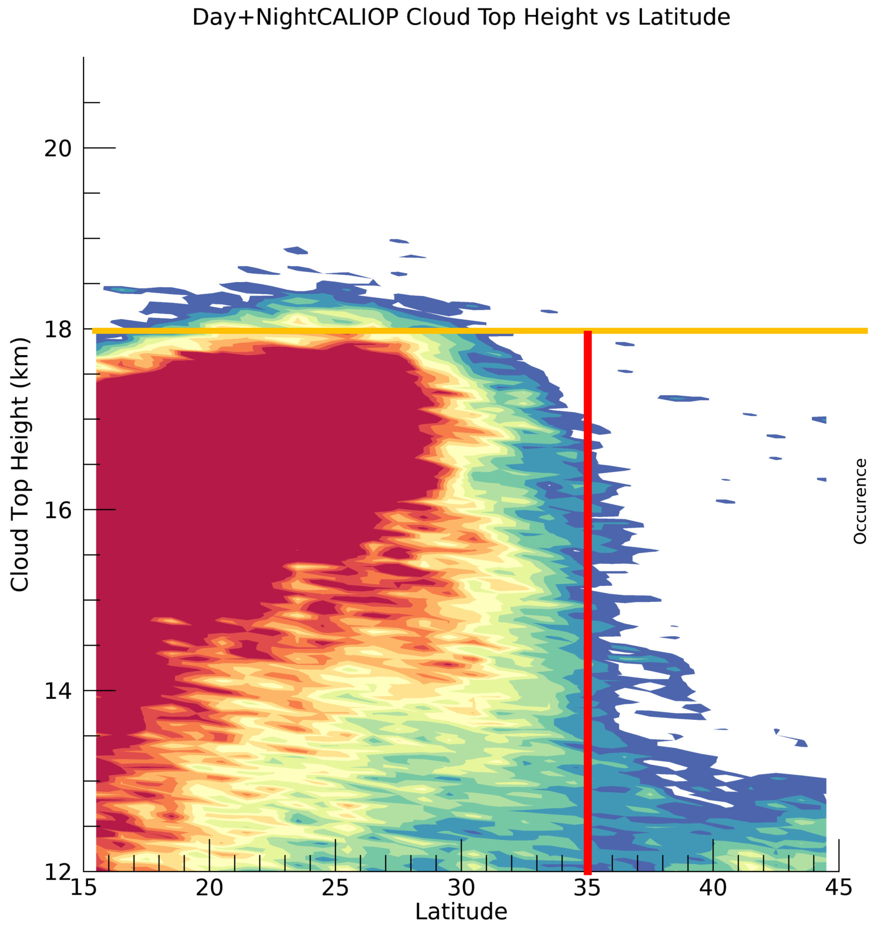


CALIOP Cloud Fraction at 16 km

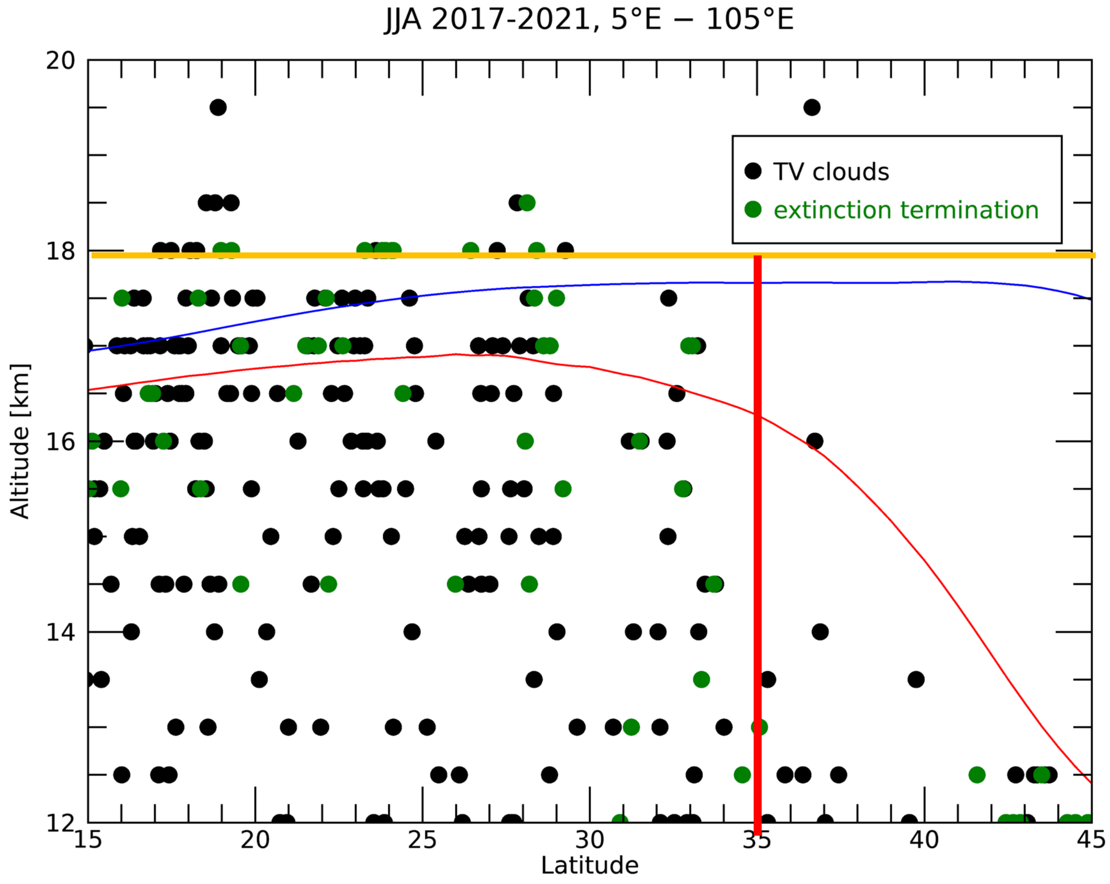
Next step is to look at tropical width in meridional segments.

CALIOP vs SAGE-III Cloud Top Observations, JJA, Asian Monsoon Region

CALIOP Cloud Top Heights



SAGE-III Cloud Top Heights – SAGE V5.2



Summary

- SAGE cloudy bin occurrence and CALIOP cirrus cloud fraction from the TV-CAD agree well using adjusted SAGE-III/ISS V5.2.
- Intermittent deep convection, as well as wave transport brings clouds and water vapor to and above the regional MERRA-2 tropopause and cold point.
- Aircraft, balloon, CALIPSO and SAGE-III/ISS observations all show that ice particles can be transported and/or formed up to 18.5 km, 400 K (or ~70 hPa).
- Asymmetries are not limited to Hemispheric; particulate distributions suggest that zonal means aren't representative.
- During the Asian Monsoon, water vapor and ozone distributions present an intriguing conundrum. Both the stratospheric circulation and convection appear to have an influence.
- Understanding the tropical tropopause region and how the troposphere and stratosphere interact across spatial and temporal scales is likely important for understanding the impact of global warming.